The other emulsification steps, in series, are a high-shear process and occur under ambient conditions as described in the emulsification step above. The shear rate temperature and pressure can be the same, similar or different than the other emulsification steps so long as the conditions are such to provide the desired mean droplet particle size.

The emulsification step is a high shear process and results in a uniform dispersion of the hydrocarbon fuel emulsion having a mean particle droplet size in the range of about 0.1 micron to about 1 micron, in one embodiment in the range of about 0.1 micron to about .95 micron, in one embodiment in the range of about 0.1 micron to about 0.8 micron, and in one embodiment in the range of about 0.1 micron to about 0.7 micron, and in one embodiment in the range of about 0.2 micron to about 0.5 micron. A critical feature of the invention is that the water phase of the aqueous fuel emulsion product is comprised of water droplets having a mean diameter of less than one micron, in another embodiment one micron to about 0.1 micron, and in another embodiment 1.0 micron to about 0.2 micron.

The emulsification occurs by any method known in the industry including but not limited to mixing, mechanical mixer agitation, static mixers, shear mixers, sonic mixers, high-pressure homogenizers, and the like. Examples of the emulsification devices include but are not limited to an Aquashear, pipeline static mixers and the like. The Aquashear is a low-pressure hydraulic shear device. The material is forced through two facing plates with drilled holes into the mixing chamber. The two plates cause counter rotational flow and allow the material to mix. The Aquashear mixers are available from Flow Process Technologies Inc.

Additional emulsification devices include high-shear devices such as IKA Works, Inc. Dispax Reactor. The IKA shear mixers use a DR3-6 with three stages of rotor/stator combinations. The tip speed of the rotor/stator generators may be varied by a variable frequency drive that controls the motor. The Silverson mixer is a two-stage mixer, which incorporates a rotor/stator design. The mixer has high-volume pumping characteristics similar to centrifugal pump. Inline shear mixers by Silverson Corporation (a rotor-stator emulsification approach); Jet Mixers (venturi-style/cavitation shear mixers), Ultrasonolator made by the Sonic Corp. (ultrasonic emulsification approach), Microfluidizer shear mixers available by Microfluidics Inc. (high-pressure homogenization shear mixers), ultrasonic mixers, and any other available high-shear mixer.

These emulsification devices have to have the ability to reduce the mean particles size of the water droplet in the range of less than one micron to about 0.1 micron or even less.

The hydrocarbon fuel, at least one emulsifier and water are emulsified to form a reactant emulsion. The reactant emulsion is formed from recycling the aqueous hydrocarbon fuel emulsion or separately by emulsifying the hydrocarbon fuel with at least one emulsifier in a separate vessel. The water may optionally contain water-soluble additives. The reactant emulsion is generally recycled in the process. The reactant emulsion may contain the same, similar or different hydrocarbon fuel and/or emulsifier than the aqueous hydrocarbon fuel. The reactant emulsion may be the same, similar or different composition as the desired aqueous hydrocarbon fuel emulsion. By using a reactant emulsion as an initial component, the overall particle size decreases and the aqueous hydrocarbon fuel emulsion stability is increased.

The hydrocarbon fuel and emulsifier contains about 50% to about 99% by weight, preferably about 85% to about 98% by weight, and more preferably about 95% to about 98% by weight hydrocarbon fuel, and it further contains about 0.05% to about 25%, preferably about 1% to about 15%, and more preferably about 1% to about 5% by weight of at least one emulsifier.

Optionally, additives may be added to the reactant emulsion, hydrocarbon fuel, emulsifier, water or combinations thereof. The additives include but are not limited to cetane improvers, organic solvents, antifreeze agents, surfactants, other additives known for their use in fuel and the like. The additives are added to the reaction emulsion, hydrocarbon fuel, emulsifier or the water, prior to and in the alternative at the first emulsification step dependent upon the solubility of the additive. The additives are generally in the range of about 1% to about 40% by weight, preferably about 5% to about 30% by weight, and more preferably about 7% to about 25% by weight of the additive emulsifier.

The water can optionally include but is not limited to the water-soluble additives such as antifreeze, ammonium nitrate, ammonium salts or mixtures thereof. Ammonium nitrate is generally added to the water mixture as an aqueous solution. In one embodiment the water, the antifreeze and/or the ammonium nitrate are mixed dynamically and fed continuously to the process. In another embodiment the water, antifreeze, ammonium nitrate or mixtures thereof flow out of separate tanks and/or combinations thereof into or mixed prior to the first emulsification step. In one

embodiment the water, water alcohol, water-ammonium nitrate, or water-alcohol ammonium nitrate mixture meets the hydrocarbon fuel additives mixture immediately prior to or in the emulsification step.

A programmable logic controller (plc) is optionally employed for governing the continuous flow of the components, thereby controlling the flow rates and mixing ratio in accordance with the prescribed blending rates. The plc stores component percentages input by the operator. The plc then uses these percentages to define volumes/flow of each component required. Continuous flow sequence is programmed into the plc. The plc electronically monitors all level switches, valve positions and fluid meters.

Example 5

This example is illustrative of making a hydrocarbon fuel emulsion product by a continuous process. A mixture having the following components was prepared.

	Concentrate	Emulsion
Diesel	---	78.12
Water	---	20.00
Emulsifier 1	40.00	0.5
Emulsifier 2	7.14	0.214
Emulsifier 3	19.80	0.297
2-ethylhexylnitrate	23.80	0.714
Ammonium Nitrate (54% by weight in water	9.26	0.15

Emulsifier 1: Reaction product of dimethylethanolamine and PIBSA (Mn-2000)
Emulsifier 2: Reaction product of dimethylethanolamine and hexadecylsuccinnic anhydride
Emulsifier 3: Reaction product of an ethylene polyamine and PIBSA (Mn-1000)

About 2.88% weight of an emulsifier reactant is added to about 97.12% weight of diesel fuel and mixed to produce a hydrocarbon fuel emulsifier mixture. The hydrocarbon fuel and emulsifier, at a flow rate of 4.95 gallons per minute (F1), was emulsified with water that had a flow rate of about 1.05 gallons per minute (F2) at room temperature along with the emulsion reactant that had a flow rate of about 6.0 gallons per minute (F4). The processing streams were introduced close to the entry portal of the shear mixer as possible. The shear mixer was a 12 GPM IKA Works Dispax mixer with three superfine mixing elements operating at about 9600 rpm (revolutions per minute). The output from this mixer (F3) was then split into two